Utilization of Parafin and TiO_2 as Phase Change Materials (PCM) for Processor Coolers

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Abstract: The development of new and renewable energy is an alternative that can be done to avoid an energy crisis. One of the most prospective energy storage techniques is thermal energy storage. Thermal energy storage technique is by utilizing the phase change of a material or known as Phase Change Material (PCM). Phase change materials (PCM) are materials that change their physical characteristics when they absorb or release heat energy. Many refrigeration technologies currently utilize PCM technology in their cooling process. (Hikma et al. 2020) AC which was originally used massively and can damage the environment can be replaced by EGACY on a regular basis. Utilization of PCM in the electronics field has begun to be developed, as research conducted by(Kandasamy, Wang, and Mujumdar 2008) found that PCM in the heat sink cavity will improve cooling performance compared to the case of a heat sink without PCM. In this study, we will try to develop a PCM-based processor cooler, by making a test tool in the form of a PCM-based processor cooling simulation. After the simulation is complete, the operational system is tested before taking data. Data collection was carried out with a combination of PCM material in the form of paraffin and TiO_2 with several variations of the mixture, namely with PCM material in the form of pure paraffin, paraffin + 2% TiO_2, paraffin + 4% TiO_2, paraffin + 6% TiO_2, paraffin + 8% TiO_2, and paraffin + 10 %TiO_2. The results showed that the addition of PCM into the heatsink can reduce the processor temperature and the addition of TiO_2 to paraffin can stabilize the temperature that occurs in the processor. The addition of 4% and 6% TuO_2 provides the best cooling effect on the processor compared to pure paraffin and TiO_2 concentrations of 2%, 8%, and 10%.

1 INTRODUCTION

The development of new and renewable energy is an alternative that can be done to avoid an energy crisis. Many things can be done to develop renewable energy, such as developing solar energy, developing micro hydro energy, developing wind energy and others. One alternative in the effort to utilize renewable energy is the development of energy storage devices, which is as important as developing renewable energy sources. Energy storage not only reduces the mismatch between supply and demand, it can also improve the performance and reliability of energy systems and play an important role in energy utilization more effectively. One of the most prospective energy storage techniques is thermal energy storage. Thermal energy storage technique is by utilizing the phase change of a material or known as Phase Change Material (PCM).

Phase change materials (PCM) are materials that change their physical characteristics when they absorb or release heat energy. Utilization of phase changes of a material in the form of liquid and solid phase changes. When a solid material is heated to a temperature above its melting point, it absorbs heat and melts. On the other hand, when a liquid is cooled below its melting point, the liquid will solidify at a constant temperature, for example water is put in a freezer until it changes to a solid phase (Ice). Furthermore, if you want to melt or condense a material that can change phase it is necessary to

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absorb or release a certain amount of energy which is called "latent heat" or "heat of fusion".

Many refrigeration technologies currently utilize PCM technology in their cooling process. (Hikma et al. 2020) Air conditioners that were originally used massively and can damage the environment can be replaced by EGACY on a regular basis, so that at night, cold temperatures can be used as a source of cooling energy that is stored first by the PCM and then released during the day. Through pipes connected to the building, air will flow into the room and then spread to all parts of the room. When this is implemented, the benefits of being an environmentally friendly, economical and of course energy efficient cooler will be obtained.(Risano, S, and Pratama 2017) The difference in the efficiency of using PCM CPO (Crude Palm Oil) in heat transfer from the inner wall to the Building Intergated Photovoltaics (BIPV) room can increase the efficiency by 5.75%. (Putra et al. 2020) A study of the performance of beeswax (PCM) phase change materials and heat pipes as a passive battery cooling system for electric vehicles resulted in the use of heat pipes to reduce the battery temperature by 26.62 °C under a heat load of 60 W compared to casing without passive cooling system. Furthermore, the addition of RT 44 on the heat pipe resulted in a maximum temperature decrease of 33.42 °C. Thus, RT 44 HC is more effective than beeswax because its melting temperature is within the battery's recommended operating temperature range, and its latent heat allows more heat to be absorbed than beeswax.

The use of PCM in the electronics field has begun to be developed, as research conducted by (Kandasamy, Wang, and Mujumdar 2008) found that PCM in the heat sink cavity will improve cooling performance compared to the case of heat sinks without PCM when the input power level is relatively high. The use of liquid metal was developed as PCM material in Heatsink by (Fan et al. 2016) liquid metal PCM materials and organic materials were compared as PCM materials in heat zinc applications, where molten metal has the ability to overcome oper heat better than organic materials (Octadecanol) and The volumetric latent heat of molten metal smelting is proportional to the latent heat of organic PCM.

Research on PCM materials is growing, currently, nano-PCM materials have been developed. This nanotechnology has also been investigated by (Bayat, Faridzadeh, and Toghraie 2018) regarding the investigation of the performance of finned heat sinks with nano-level phase change materials (NePCM) where the addition of a small portion of nanoparticles (2%), heat sink performance can be increased up to PCM. melted completely. Increasing the percentage of nanoparticles, can cause a decrease in the performance of heat zinc. With the addition of 2% aluminum oxide nanoparticles can produce better heatsink performance compared to the case of adding copper oxide with the same percentage.

The development of PCM on processor cooling has not been widely developed, because the microprocessor is susceptible to liquid fluid which results in the failure of the processor performance. Previous research has been done on processor cooling by using liquid fluid that flows through heat zinc, where the results of the multi-channel flow model provide a better cooling effect than the pool-shaped flow model. In this study, it will be tried to develop the use of local materials, namely lard as PCM material combined with faraffin wax in processor cooling.

2 PHASE CHANGE MATERIAL (PCM)

PCM can be classified into two, namely organic and anorganic. This grouping is based on the melting point and latent heat of fusion. There is no single material that can fulfill all the desired properties, so PCM is also developed which is a combination of 2 groups of materials (Sharma et al. 2009).

2.1 Organic PCM

Usually organic PCM has a low temperature range, is expensive and has a low average latent heat per unit volume and density. Most organic PCMs are flammable in nature. Organic PCM can be distinguished as paraffin and non-paraffin.

2.1.1 Paraffins

Paraffins consist of a mixture of mostly straight chain n-alkanes CH_3-(CH_2)-CH_3. Crystallization of the chain (CH_3)- releases some latent heat. The melting point and latent heat of fusion increase with the length of the chain. The quality of paraffin as a smelting heat storage material is caused by its wide temperature range. Some of the melting points and latent heat of smelting of paraffin can be seen in Table 1.

Table 1: Melting Point and Latent Heat of Melting Some Types of Paraffins.

Number of Atom C	Melting Poin (°C)	Latent Heat of Melting (kJ/kg)
14	5.5	228
15	10	205
16	16.7	237.1
17	21.7	213
18	28.0	244
19	32.0	222
20	36.7	246
21	40.2	200
22	44.0	249
23	47.5	232
24	50.6	255
25	49.4	238
26	56.3	256
27	58.8	236
28	61.6	253

Source: Sharma et al.2009

2.1.2 Nonparaffin

PCM from non-paraffin materials is PCM that is commonly encountered with quite a lot of variation in properties. Each of these materials has special characteristics / properties unlike paraffin which has almost the same properties. This type is the most common category of PCM. Among the non-paraffinic materials, the most common types are esters, fatty acids, alcohols and glycol types (Abhat et al. 1981). This group is often further subdivided into groups of fatty acids and other nonparaffinic organics. These materials are generally flammable and should not be exposed to high temperatures, near flames and oxidizing agents. The description of non-paraffin PCM can be seen in Table 2, while the fatty acid PCM can be seen in Table 3.

Table 2: Melting Point and Latent Heat of Melting Some Non Paraffin.

Materials	Melting Point (°C)	Latent Heat of Melting (kJ/kg)
Formic acid	7.8	247
Caprilic acid	16.3	149
Glycerine	17.9	198.7
α-Lactic acid	26	184
Methyl palmitat	29	205
Phenol	41	120
Bee wax	61.8	177
Gyolic acid	63	109
Azobenzene	67.1	121
Acrylic acid	68.0	115
Glutaric acid	97.5	156
Catechol	104.3	207
Quenon	115	171
Benzoic acid	124	167
Benzamide	127.2	169.4
Oxalate	54.3	178
Alpha naphol	96	163

Source: Sharma et al.2009

Table 3: Melting Point Heat of Latent Melting Some Fatty Acids.

Materials	Melting Point (°C)	Latent Heat of Melting (kJ/kg)
Acetic acid	16.7	184
Poly ethylene glycol	20.25	146
Capric acid	36	152
Eladic acid	47	218
Lauric acid	49	178
Pentadecanoic acid	52.5	178
Tristearin	56	190
Mirystic acid	58	199
Palmatic acid	55	163
Stearic acid	69.4	199
Acetamide	81	141

Source: Sharma et al.2009

2.2 Anorganic

PCM anorganic PCM is classified as salt hydrate and metallic. This type of PCM is not very cold and the heat of fusion will not decrease during rotation.

2.2.1 Hydrates of Salts

Hydrates of salt can be seen as mixtures of inorganic salts with water to form certain crystalline solids of the general formula AB.nH2O. The solid-liquid change of the salt hydrate is a dehydration process of the salt hydration. Salt hydrates usually melt into a salt hydrate with very small moles of water.

$$AB.nH2O \rightarrow AB.mH2O + (n\text{-}m)H2O$$

or into anhydrous form,

$$AB.nH2O \rightarrow AB + nH2O$$

At their melting point, the hydrate crystals split into anhydrous salt and water or into a lower hydrate and water. Salt hydrates are the most important and widely studied type of PCM in energy storage systems. The most prominent properties of this type of PCM are high latent heat of fusion per unit volume, relatively high thermal conductivity (almost twice that of paraffin) and small volume change during melting. This type of PCM is also less corrosive, compatible with plastics and only a few types are toxic. Many types of salt hydrates are inexpensive to use as heat stores. In Table 4 it can be seen several types of PCM from salt hydrates.

Table 4: Melting Point and Latent Heat of Melting Some Salt Hydrates.

Materials	**Melting Point (°C)**	**Latent Heat of Melting (kJ/kg)**
$K_2HPO_4.6H_2O$	14,0	109
$FeBr3.6H_2O$	21,0	105
$Mn(NO_3)_2.6H_2O$	25,5	148
$FeBr_3.6H_2O$	27,0	105
$CaCl_2.12H_2O$	29,8	174
$LiNO_3.2H_2O$	30,0	296
$LiNO_3.3H_2O$	30	267
$Na_2O_3.10H_2O$	32,0	241
$Na_2SO_4.10H_2O$	32,4	173
KFe(SO4)2.12H20	33	138
$CaBr_2.6H_2O$	34	124
$LiBr_2.2H_2O$	34	134
$Zn(NO_3)_2.6H_2O$	36,1	223

Source: Sharma et al.2009

2.2.2 Metals

This type of metal also includes metals with low melting points and metal alloys. This type of PCM has not received much attention because it is very heavy. If volume is a concern, this type is the choice because it has a high latent heat of fusion per unit volume. This metal has a high thermal conductivity so that no additional heavy filler is needed. A list of some metallic materials can be seen in Table 5.

Table 5: Melting Point and Latent Melting Heat of Some Metallics.

Materials	**Melting Point (°C)**	**Latent Heat of Melting (kJ/kg)**
Gallium-gallium Antimony eutectic	29,8	-
Gallium	30,0	80,3
Cerrolow eutectic	58	90,9
Bi-Cd-In eutectic	61	25
Cerrobend eutectic	70	32,6
Bi-Pb-In eutectic	70	29
Bi-In eutectic	72	25
Bi-Pb-tin eutectic	96	-
Bi-Pb eutectic	125	-

Source: Sharma et al.2009

2.3 PCM Combination

PCM combination is a composition with the lowest melting point of two or more components, each of which melts and solidifies to form a mixture of crystalline components during the crystallization process (George 1989). This type of PCM almost always melts and solidifies without separation because they solidify into a crystalline mixture, giving the components little chance to separate. At the time of melting the two components melt sequentially with unwanted separation.

Table 6: List of PCM Combinations of Organic-Anorganic.

Materials	**Melting Point (°C)**	**Latent Heat of Melting (kJ/kg)**
$CaCl_2.6H_2O+CaBr_2.6H_2O$	14,4	140
Triethylethane+water+urea	13,4	160
$CaCl_2+MgCl_2+6H_2O$	25	95
NH_3CONH_2+ NH_3CONH_2	27	163
Naphtalene+benzoic acid	67	123,4
Freezer salt	-50	325
Freezer salt	-23	330
Freezer salt	-16	330

Source: Sharma et al.2009

2.4 State of the Art

(Hosseinizadeh, Tan, and Moosania 2011) This study compared heatsinks with different numbers of fins to cool electronic components, where the results obtained in heat absorption from a heat zing source with 7 fins gave an average temperature at low heat zing. Thicker heat zing results in better heat zing performance and 4 mm and 6 mm thickness have the best effectiveness in absorbing heat from the source. The higher the fin, the lower the heat zing temperature. (Markandeyulu, Krishna Devanuri, and Kiran Kumar 2016) For thermal management of electronic components, PCM can be a promising option because it does not need external assistance and because of its compatibility in size. PCM can remove heat from electronic components at a constant temperature where the temperature rise can be effectively limited. By using PCM, product failures and assembly failures can be reduced which can further lead to an increase in productivity. The main problem with PCM is its low thermal conductivity. This problem can be overcome by adding high thermal conductivity materials (eg conductivity enhancers), nanoparticles, matrix metal foam and metal fins. (Rehman et al. 2018) The results show that the heat zing performance with PCM is better than the heat zing performance without PCM. The higher volume fraction of PCM results in more drop in heat zing temperature at the same input power. Different PCM materials exhibit different behavior. (Fan et al. 2016) The results showed that PCM material with molten metal had a greater impact on temperature reduction on heat zing than 1-octadecanol organic PCM material. Judging from the protection time, the liquid metal has a protection twice as long as 1-octadecanol. (Wang et al. 2021) Higher alcohol/graphite foam PCM materials have the ability to lower the heat zing temperature better than PCM materials using higher alcohol with a better percentage of 24%. The heat capacity of PCM higher alcohol/graphite foam material reaches 102.32 J/K with a thermal conductivity of 54.22 W/cm2.

3 EXPERIMENT SETUP AND PROCEDURE

3.1 Research Design

This study was designed using simulation, where the processor simulated as a source of heat energy, so a heater with a power of 120 W is made with a heat capacity of 40 - 70 ^oC where this temperature is the operating temperature of the processor. The heatsink is made with dimensions of 73 x 73 x 55 mm, as shown in Figure 1.

PCM material uses paraffin base material with several variations of TiO_2 concentration and the test device will be made as shown in Figure 2.

3.2 Determination of Data Sources

The data used in this study is primary data in the form of temperature data obtained from temperature measurements placed on the heatsink using a thermocouple and other primary data in the form of a mixture of PCM material, namely paraffin and TiO_2. In addition to primary data, secondary data is also obtained from related research data sources in the form of PCM material characteristics.

3.3 Research Variables

The variables of this study are independent variables, dependent variables and control variables. The independent variables in this study are PCM material and the shape of the heatsink that is made to vary. The dependent variable is the temperature generated by the system due to changes in the variation of the PCM material and the shape of the Heatsink. As a control variable, namely the input power given to the system.

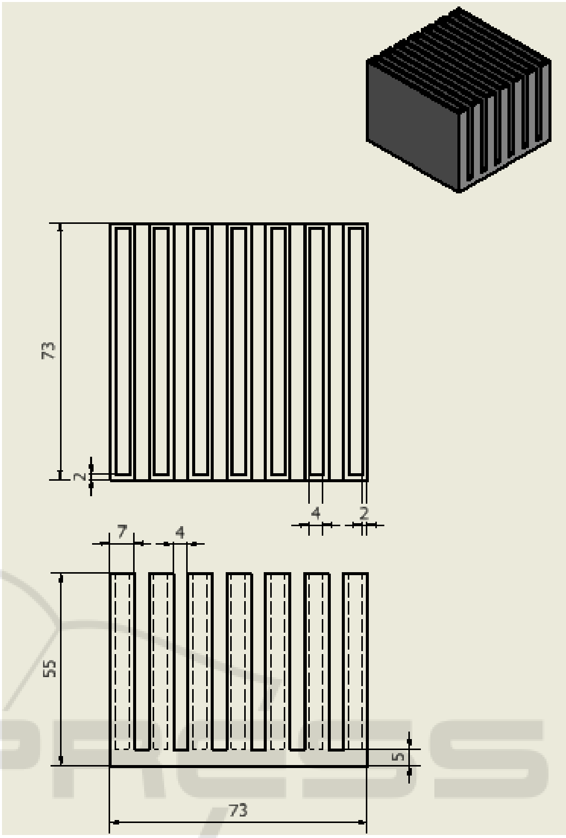
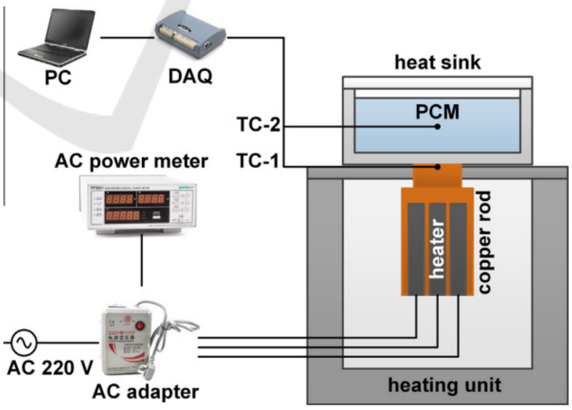


Figure 1: Heatsink Model.



(Fan et al. 2016)

Figure 2: Model Design Test Equipment.

3.4 Research Materials

The materials used in this research are PCM materials in the form of paraffin and TiO2, and the selected heatsink material is aluminum because it has good heat conductivity.

3.5 Research Instruments

Several research instruments used in this study are temperature measuring instruments, namely thermocouples, AC power meters which are used to supply power to the system, AC Adapter which functions to convert alternating current (AC current) into direct current (DC current), one for the heating unit that functions as a heat source as a simulation of the processor heat, Digital PID Temperature Controller to read the temperature, Solid State Relay SSR 25A to disconnect and connect current to the heating system which is controlled via digital PID.

3.6 Research Procedure

This research will begin by making a test instrument in the form of a PCM-based processor cooling simulation. After the simulation is complete, the operational system is tested before taking data. Data collection was carried out with a combination of parafin and TiO_2 with a mixture as shown in table 7.

Table 7: Sample Mixture of Paraffin and TiO_2 as PCM.

No	Mixed Percentage (%)	
	Parafin	TiO_2
1	100	0
2	98	2
3	96	4
4	94	6
5	92	8
6	90	10

3.7 Data Analysis Methods

In this study, the data analysis method used is a descriptive statistical method. Temperature data obtained from measurements are presented in tabular form or in graphical form as a basis for making decisions. The data will be further processed so that it is known the effect of using PCM and the shape of the Heatsink on the cooling effectiveness of the processor. In addition to temperature data, photo data obtained from digital cameras that are used to observe phenomena that occur in PCM materials during testing will be analyzed qualitatively.

4 RESULTS AND DISCUSSION

Simulated processor temperature by heating with heatsink cooling without PCM, heatsink with PCM using pure paraffin and heatsink with PCM material with some mixture of paraffin and TiO2 can be seen in Figure 3.

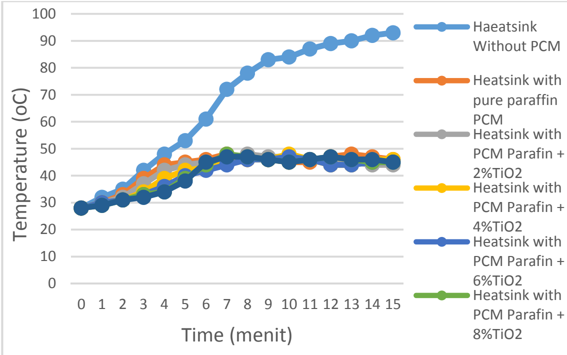


Figure 3: Chart of the effect of adding PCM to the heatsink on the cooling effect of the processor.

From Figure 3, it can be seen that the cooling of the processor with a heatsink without a PCM shows that the temperature continues to increase from 0 seconds to 150 seconds, and the processor temperature reaches 93 °C in 150 seconds. Processor temperature that continues to increase due to cooling by conduction method from the processor to the heatsink and free convection alone is not able to eliminate the presence of heat in the processor. The addition of paraffin to the heatsink is able to stabilize the temperature on the processor below 50 °C. The use of TiO2 mixed with paraffin as PCM material is able to increase the thermal conductivity of PCM as evidenced by the faster cooling effect that occurs in the processor, where the greater the TiO2 content given to paraffin, the faster the cooling effect.

4.1 Effect of Using Heatsink without PCM on Processor Cooling

Cooling with heatsink without PCM shows a significant increase in processor temperature starting from 0 minutes to 15 minutes continues to increase. The processor temperature at 47 °C only lasted until the first 3 minutes, then the processor temperature continued to increase, meaning that cooling the processor only by relying on the heatsink was not enough, maybe because the area of conduction heat transfer from the processor to the heatsink was not enough. Figure 4 shows the power input On at minute 1 to minute 3 then at minute 4 the power input is Off and the 5th minute is On again and so on. The input power is set at a temperature of 47 °C if the processor temperature reaches 47 °C then the input power is Off and if the processor temperature is below 46 °C then the input power is On.

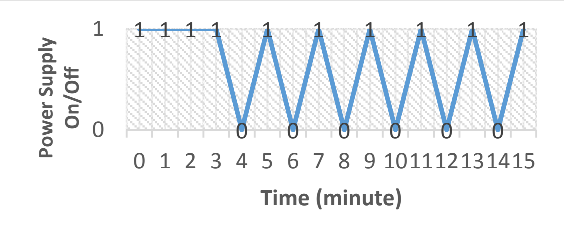


Figure 4: Input Power On/Off On Processor Cooling with Heatsink without PCM.

4.2 Effect of Using Heatsink with PCM Made of Pure Paraffin

The addition of pure paraffin to the heatsink affects the cooling effect on the processor, where the processor reaches the 7th minute the temperature is still below 47 ºC which is indicated by the supply the power is in the On position and at the 8th minute the power supply is Off, meaning that the processor temperature has reached 47oC or more and at the 9th minute the power supply is On, it means that the processor temperature is below 47ºC, this is because at a temperature of 47ºC the paraffin has started to melt so it absorbs heat that occurs in the processor so that the processor temperature drops again. In the 13th to 15th minute the power supply is turned off again because the temperature that has occurred has reached 47 ºC or more and at the 15th minute the power supply is back on. An overview of On/Off Supply power based on heating time can be seen in Figure 5.

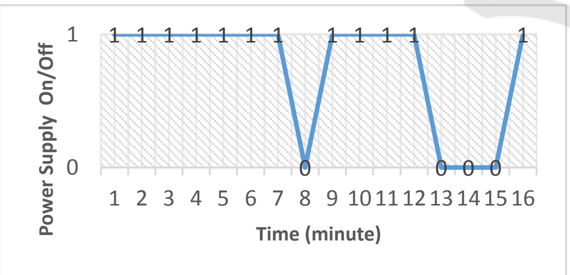


Figure 5: Input Power On/Off On Processor Cooling with Heatsink Using Pure Paraffin As PCM.

4.3 Effect of Using Heatsink with PCM Made of Paraffin + 2% TiO_2

The addition of a mixture of paraffin + 2% TiO2 on the heatsink has an impact on the temperature that occurs in the processor. With the addition of 2% TiO_2 to paraffin, it provides a fairly stable cooling effect, as evidenced by the persistence of the processor temperature below 47 ºC until the 8th minute and at the 9th - 11th minute the temperature is still in the range of 47 ºC - 48 ºC, then at the 12th minute up to 15 minutes the processor temperature is below 47 ºC Again, due to the PCM material on the heatsink has melted and the process of absorbing heat from the processor to the heatsing occurs. An overview of On/Off Supply of power based on heating time can be seen in Figure 6.

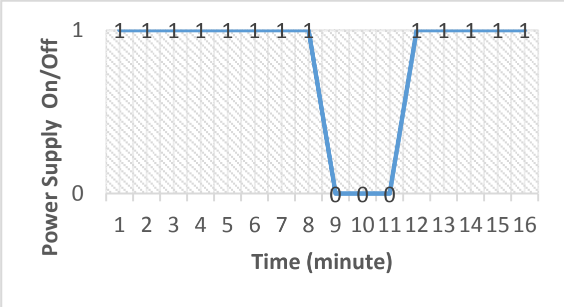


Figure 6: Input Power On/Off in Processor Cooling with Heatsink Using Paraffin + 2% TiO_2 as PCM.

4.4 Effect of Using Heatsink with PCM Made of Paraffin + 4% TiO_2

Addition of a mixture of paraffin + 4% TiO_2 to the heatsink has an impact on the temperature that occurs on the processor. With the addition of 4% TiO_2 in paraffin, it provides a fairly stable cooling effect where the processor temperature is only at 10 minutes which exceeds 47ºC, as evidenced by the power supply being On at all times except Off at 10 minutes. This shows that the addition of 4% TiO_2 to paraffin has a significant impact on the cooling process of the processor. An overview of On/Off Supply of power based on heating time can be seen in Figure 7.

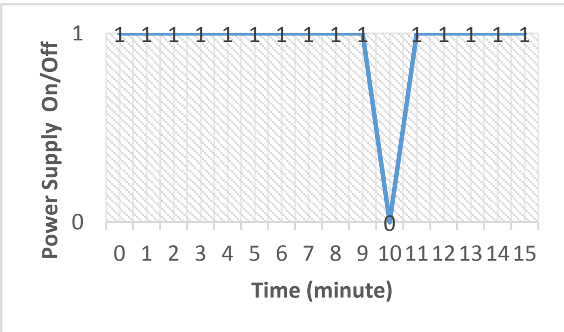


Figure 7: Input Power On/Off In Processor Cooling with Heatsink Using Paraffin + 4% TiO_2 As PCM.

4.5 Effect of Heatsink Utilization with PCM Made of Paraffin +6% TiO_2

The addition of a mixture of paraffin + 6% TiO_2 on the heatsink has an impact on the temperature that occurs on the processor. With the addition of 6% TiO_2 to paraffin, it provides a fairly stable cooling effect where the processor temperature is only at 10 minutes which exceeds 47^{o}C, as evidenced by the power supply being On at all times except Off at 10 minutes. This shows that the addition of 6% TiO_2 to paraffin has a significant impact on the cooling process of the processor. The difference with 4% TiO_2 content is in the temperature difference at each time, which is the overall processor temperature at each time is lower than PCM with 4% TiO_2 content. An overview of On/Off Supply of power based on heating time can be seen in Figure 8.

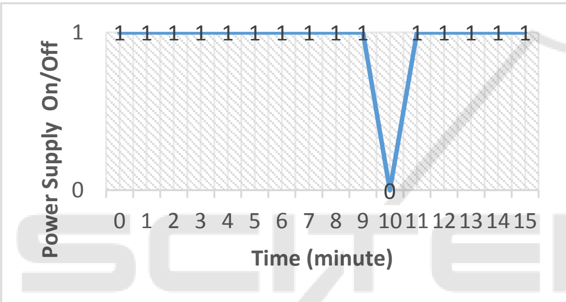


Figure 8: Input Power On/Off on Processor Cooling with Heatsink Using Paraffin + 6% TiO_2 As PCM.

4.6 Effect of Using Heatsink with PCM Made of Paraffin +8% TiO_2

The addition of a mixture of paraffin + 8% TiO_2 on the heatsink has an impact on the temperature that occurs on the processor. With the addition of 8% TiO_2 to paraffin, the temperature effect in the early minutes is lower than the percentage of TiO_2 below 8%, but the achievement of temperatures above 47 ^{o}C is also faster. In this mixture of paraffin + 8% TiO_2, the processor temperature is also less stable, as shown in Figure 9. On/Off fluctuations occur in the power supply due to temperature fluctuations that occur in the processor due to an increase in the conductivity of the PCM material which causes the PCM material to melt earlier.

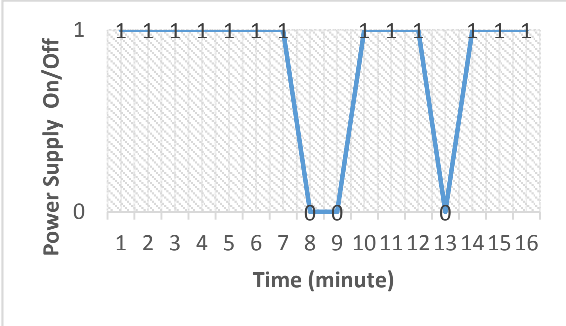


Figure 9: Input Power On/Off on Processor Cooling with Heatsink Using Paraffin + 8% TiO_2 As PCM.

4.7 Effect of Using Heatsink with PCM Made of Paraffin + 10% TiO_2

The addition of a mixture of paraffin + 10% TiO_2 on the heatsink has an impact on the unstable temperature that occurs in the processor. Processor temperature characteristics that occur in a mixture of paraffin + 10% TiO_2 are almost similar to a mixture of paraffin + PCM 8% TiO_2. An overview of On/Off Supply of power based on heating time can be seen in Figure 10.

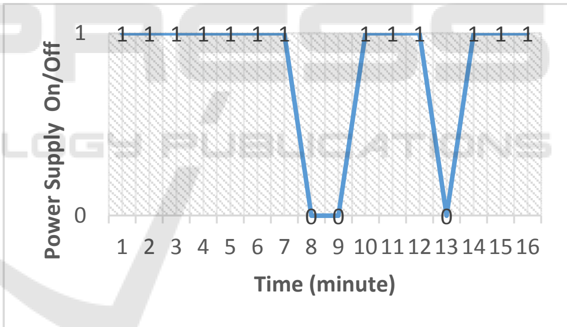


Figure 10: Input Power On/Off on Processor Cooling with Heatsink Using Paraffin + 8% TiO_2 As PCM.

5 CONCLUSION

From the research that has been done, it can be concluded as follows:

1. The addition of PCM to the heatsink has a significant effect on the temperature that occurs in the processor, where the addition of PCM to heatzing can reduce the temperature that occurs in the processor compared to using a heatsink without PCM.

2. The addition of TiO2 concentration in paraffin as PCM material can stabilize the temperature that occurs in the processor.
3. The addition of 4% and 6% TiO2 concentrations in paraffin gave the best impact on processor cooling.

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